Cardiac Risks and Complications of Noncardiac Surgery

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Editor's Comment: This is the third in a series of papers being exchanged by **ANNALS OF INTERNAL MEDICINE** *and* **ANNALS OF SURGERY** *for republication with the view that specially selected subjects will be of considerable interest to the readers of these journals and are exchanged accordingly.*

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When internists are consulted to assess risks and to aid in the perioperative management of surgical patients, they often can rely on substantial clinical data to guide the consultation. Perioperative cardiac risk can be estimated based on the severity of underlying heart failure, the occurrence of a recent myocardial infarction or various arrhythmias, the presence of aortic stenosis, the patient's age, the type of planned surgery (including whether it is an emergency or elective procedure), and the patient's general medical condition. Preoperative exercise testing or cardiac catheterization to assess risk are not routinely indicated, but perioperative hemodynamic monitoring to improve management is recommended in patients at high risk. Postoperative hypertension, arrhythmias, and heart failure commonly occur in the first 2 days after surgery, but the risk of myocardial infarction persists for at least 5 or 6 days after surgery. Effective perioperative consultation must include careful postoperative observation to detect cardiac complications at an early stage and to assist in their management.

As SURGICAL TECHNIQUES have become more refined, an increasing percentage of the morbidity and mortality associated with general surgery now relates to cardiac complications rather than to direct surgical problems. A discussion of cardiac complications of general surgery is especially pertinent as the population ages and as surgeons attempt increasingly more ambitious procedures.

When a medical physician is asked to give a preoperative evaluation on a patient, the consultation should be approached with several purposes in mind. First, based on the patient's history and findings on physical examination, what is the patient's predicted risk of cardiac complications with surgery and how can the consultant, the surgeon, and the anesthesiologist compare overall surgical to nonsurgical risk? Second, what special preoperative, intraoperative, or early postoperative management strategies might be recommended to minimize risks? Third, the consulting physician must decide what particular complications or problems are most likely to occur during the postoperative period so that early signs of such complications might be detected and effective intervention instituted.

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Preoperative Estimation of Cardiac Risk

Although American adults have only about a 0.2% risk of a myocardial infarction or cardiac death associated with general anesthesia and surgery,[1,2] it has long been appreciated that patients with ischemic heart disease have substantially higher risk.[2-6] Whereas the early literature pooled patients with all kinds of symptoms from ischemic heart disease, later studies have emphasized that a recent preoperative myocardial infarction is by far the most important individual factor[2,4,6-9] and that the risk of a recurrent myocardial infarction or cardiac death is significantly higher in patients having surgery within 6 months after a myocardial infarction. Although none of these individual studies had enough patients to show any significant trends within the first 6 months, pooled data from three of the larger studies in the 1960s and 1970s[2,7,8] indicate that recurrent myocardial infarction or cardiac death occurred in about 30% of patients having surgery within 3 months after a myocardial infarction and in about 15% of patients having surgery between 3 to 6 months after an infarction. If a patient has survived for 6 months after an infarction, the risk of a recurrent infarction or cardiac death declines to about 5% and remains constant regardless of how much longer the patient survives. Although one early study[6] reported a lower risk after preoperative subendocardial myocardial infarctions

than after transmural infarctions, our data[8,10] showed virtually identical risks after both types of infarctions. Our data are consistent with the overwhelming evidence from the literature that the prognosis for survivors of subendocardial infarctions is similar to that for survivors of transmural infarctions.[11,12]

Very recently, data have suggested that the risk of surgery in patients who have had recent myocardial infarctions may be lower now than it was in the mid-1970s,[13,14] presumably because the advances in anesthesia for patients having cardiac surgery are now being applied to patients at high risk having general surgery. Wells and Kaplan[13] reported no infarctions but a 15% risk of significant atrial and ventricular arrhythmias in 48 patients who had surgical procedures within 3 months of an infarction, and Rao and El-Etr[14] reported a reinfarction rate of 8% in patients having surgery within 3 months of an infarction and only 3.5% in those having surgery between 3 and 6 months after an infarction. Although in neither of these two studies have data been reported on the type of surgical procedures or other cardiac risk factors, it would not be surprising if careful patient selection, optimal preoperative assessment, and management of other cardiac and noncardiac problems, and the use of hemodynamic monitoring (for example, intra-arterial catheters and pulmonary artery catheters) allowed for lower mortality rates than those quoted in earlier studies of patients after infarction.

TABLE 1. *Correlation Between Signs and Symptoms of Preoperative Heart Failure and Risk of Perioperative Pulmonary Edema after Major Surgery in Patients over Age 40**

	Total Patients (*n*)	Percent Developing Cardiogenic Pulmonary Edema (%)
No history of congestive heart failure	853	2†
History of left heart failure but not evident on preoperative examination or chest roentgenogram	87	6†
Left heart failure by preoperative physical examination or chest roentgenogram	66	16†
Preoperative NYHA functional class for congestive heart failure		
I	935	
II	15	7
III	34	6
IV	17	25‡
History of pulmonary edema	22	23§
S3 Gallop	17	35§
Jugular venous distention and signs of left heart failure	23	30§

* Adapted from Goldman and associates (10).
† $p < 0.01$ for all pairs.
‡ $p < 0.001$ for class IV *vs.* all others.
§ $p < 0.01$ when comparing patients with to those without these findings.

Preoperative Congestive Heart Failure

Another major correlate of postoperative cardiac problems is preoperative congestive heart failure (Table 1). Patients who have third heart sounds or distended jugular veins at preoperative examination have especially high risk for postoperative pulmonary edema. Interestingly, these two physical findings were also shown to be the most specific predictors of catheterization-documented congestive heart failure in patients with coronary artery disease.[15] Similarly, patients with a preoperative history of pulmonary edema or with evidence of congestive heart failure by preoperative physical examination and chest roentgenogram have markedly increased risk for perioperative pulmonary edema; this risk increases as the preoperative New York Heart Association (NYHA) class of congestive heart failure worsens.[5,10] If patients have no history of congestive heart failure, the new onset of severe heart failure or pulmonary edema after surgery is very unusual, except in those who are over age 60 years, have baseline electrocardiographic abnormalities, and have major abdominal or thoracic operations.[10] Although there are no controlled trials to document the point, observational data[10] indicate that patients whose congestive heart failure is well controlled before surgery are at substantially less risk than those whose heart failure is not adequately controlled. The medical physician, however, must be careful about the diuresis of patients with preoperative congestive heart failure. For example, medical physicians commonly treat congestive heart failure by trying to achieve a maximal in-hospital diuresis because they expect that patients will not be so rigorous in following the diet or medication regimen after discharge. Such aggressive diuresis of preoperative patients may be hazardous because the immediate peripheral vasodilitation induced by both general and spinal anesthesia may cause severe hypotension in volume-depleted patients. Thus, as a general guideline, preoperative diuresis should be sufficient to control congestive heart failure but not so vigorous as to cause any signs of postural hypotension.

Patients with significant valvular heart disease have increased risks of cardiac complications from general surgery, partly because they often have underlying heart failure. During the perioperative period, about 20% of patients with important valvular heart disease will have new or worsening heart failure,[5,10] which is sometimes, but not always, precipitated by supraventricular tachyarrhythmias. Valvular aortic stenosis is especially likely to be associated with difficulties in perioperative fluid management, and presence of this disorder will often lead to a change in the routine surgical plan.

TABLE 2. *Risk of Major Cardiac Complications in Different Types of Operative Procedures in Patients over Age 40**

	Intrathoracic, Intraperitoneal, or Aortic Procedures (n = 437) (n (%))	Other Major Noncardiac Procedures (n = 564) (n (%))
New perioperative supraventricular tachycardia	28 (6)	13 (2)
Pulmonary edema	23 (5)	2 (0.4)
Myocardial infarction	11 (2.5)	7 (1)
Death from cardiac causes	11 (2.5)	8 (1)

* Adapted from Goldman and associates.[8,10]

Preoperative Arrhythmias

Patients with pre-existing arrhythmias, especially frequent premature ventricular contractions or rhythms other than normal sinus rhythm, also have increased risk for perioperative cardiac complications.[5,8,10] These complications are commonly the same types of ischemic and congestive complications that other patients develop, rather than being specific arrhythmic problems. Thus, just as arrhythmias in ambulatory patients seem to be a marker of more serious coronary artery disease and ventricular dysfunction,[16,17] they are also a marker of more severe heart disease in patients who are about to undergo surgery. However, frequent premature ventricular contractions carry this increased risk only in patients with underlying heart disease; otherwise healthy persons who have no evidence of heart disease despite a full clinical evaluation do not have a diminished life expectancy[18] and should not be at increased surgical risk.

Age and Type of Surgery

Although older patients often have other risk factors for surgery, data suggest that age itself is a very important predictor of cardiac complications.[5,8,10] In our series, the risk of perioperative cardiac death was increased about tenfold for patients older than age 70 years.[8,10]

In almost every study it has been found that the type of operation is significantly related to cardiac complications (Table 2), with all types of cardiac complications being more likely after major intra-abdominal, intrathoracic, or aortic procedures.[8] In contrast, after controlling for the type of surgery, the length of surgery has not correlated with cardiac complications;[6,10] in one series,[5] the length of surgery was actually inversely correlated with cardiac complications after controlling for the type of surgery. Cardiac complications are up to four times more common after emergency operations than they are after elective procedures.[5,8,10]

Patients who develop cardiac problems after surgery often have surgical problems that precipitate or complicate their cardiac condition.[8,10,19] Thus, it is not surprising that preoperative evidence of a poor general medical condition (including hypoxia, carbon dioxide retention, hypokalemia, acidosis, abnormal renal or liver function, or being bedridden from a chronic disease) are associated with higher risks of postoperative cardiac complications.[8]

Multifactorial Assessment of Risk

Because of the many potential causes of perioperative cardiac complications, multivariate analysis is the best method to determine which factors independently predict the development of complications. In our series of 1001 patients over age 40 years who had major noncardiac and non-neurologic surgery, nine factors from the history, physical examination, electrocardiogram, laboratory data, and the operation (Table 3) were used to group patients into categories with very different risks of cardiac complications (Table 1). Based on the nine important factors, over one half of the patients were in a low-risk class I group (0 to 5 points), in which 99% of the patients had either no or only minor cardiac complications, 0.7% had life-threatening complications (myocardial infarction, pulmonary edema, or ventricular tachycardia) but did not die from cardiac causes, and 0.2% died from cardiac causes. In patients of the class II risk group (6 to 12 points), the probability of a life-threatening but nonfatal cardiac complication increased to 5% and the probability of cardiac death was 2%. In patients of the class III risk group (13 to 25 points), the probability of a life-threatening but nonfatal cardiac complication increased to 11%, but the risk of death from cardiac causes remained low at 2%. In those of the class IV risk group (26 or more points), however, 22% of the patients had life-threatening but nonfatal cardiac complications, and another 56% died from cardiac causes. In our study, 10 of the 19 deaths from cardiac complications occurred in the 18 patients who were in class IV.

Although the data for this risk index were gathered prospectively, the index itself was derived retrospectively. Any index needs prospective local testing before it can be used confidently in a particular hospital. Also, any risk estimate is approximate and must be interpreted as such. Nevertheless, the multifactorial index has done well in three prospective tests at other institutions. In data from a series of 1000 patients 70 years of age and older at Barnes Hospital in St. Louis[20] (Stephen CR. Personal communication), 29 of 34 patients who died from cardiac complications of noncardiac surgery were in risk classes III or IV by the multifactorial index. In the experience of Kaplan and Dunbar,[21] the prevalance of life-threatening cardiac complications correlated well with the risk index,

and the index was particularly more accurate than the American Society of Anesthesiologists' physical status score in assessing risk among patients who had general surgery after coronary artery bypass surgery. Finally, in a prospective evaluation of over 1100 patients, the likelihood of life-threatening or fatal cardiac complications corresponded very closely to what was predicted by the multifactorial index, except for class IV patients who had only about 40% of the predicted complications, perhaps in part because their high risk was recognized and extra precautions or interventions were instituted (Zeldin RA. Personal communication).

It should also be emphasized that the multifactorial approach to cardiac risk seems to be more reliable than estimates based on just one factor. For example, even patients with recent myocardial infarctions can be subdivided into very-high-risk *vs.* moderate-risk groups based on whether they had other major cardiac risk factors. Such a finding is not surprising based on the known marked difference in prognosis in patients with complicated *vs.* uncomplicated myocardial infarctions,[22,23] and the clinical guideline that patients without complications can walk about and be discharged very early after a myocardial infarction.[24] It should also be noted that several studies[2,3] that report cardiac risks after a recent preoperative infarction have not distinguished nonfatal reinfarction from cardiac death. Among patients in the risk class III group by the multifactorial index, including some patients having needed but semielective surgery within 6 months of an infarction, the index estimates an 11% chance of having nonfatal complications (including nonfatal reinfarction), as well as a lower risk of cardiac death. Recent reports of very low death rates in patients with infarctions within 6 months of operation[13,14] may also be partly explained by the selection of patients in class III rather than class IV for surgery. Nevertheless, prudence dictates that risks and benefits be carefully weighed in a patient who is within 6 months of infarction, and surgery should be postponed unless the risks of delaying the procedure outweigh the cardiac benefits.

Also noteworthy are the factors that do not appear to have a major independent effect on the risk of cardiac complications. For example, although others[7] have reported univariate data showing that hypertension increases the risks of anesthesia and surgery, we found no increased risk of hypertension after controlling for the preceding factors.[8,25] Similarly, epidemiologic risk factors such as hyperlipidemia or smoking, which often correlate with the eventual development of ischemic heart disease, did not predict cardiac complications after surgery. Most surprisingly, although patients with stable angina had about a threefold increased risk of cardiac complications, stable angina was not a significant risk factor after controlling for the factors in the index. It may be that a series with several thousand patients could show that the small increase in risk associated with stable angina pectoris could eventually become statistically significant, but clearly if stable angina pectoris is the only evidence of ischemic heart disease, the risks associated with general anesthesia and surgery are not dramatically increased. However, this principle cannot be extended to patients with class IV angina or accelerating angina. Because accelerating or class IV angina may carry a risk analogous to that of a recent myocardial infarction, such patients should have their angina well controlled before surgery with the expectation that effective preoperative therapy will likely reduce surgical risk.

TABLE 3. *Computation of Multifactorial Index Score to Estimate Cardiac Risk in Noncardiac Surgery**

	Points
S3 gallop or jugular venous distention on preoperative physical examination	11
Transmural or subendocardial myocardial infarction in the previous 6 months	10
Premature ventricular beats, more than 5/min documented at any time	7
Rhythm other than sinus or presence of premature atrial contractions on last preoperative electrocardiogram	7
Age over 70 years	5
Emergency operation	4
Intrathoracic, intraperitoneal, or aortic site of surgery	3
Evidence for important valvular aortic stenosis†	3
Poor general medical condition‡	3

* Adapted from Goldman and associates.[8]

† Findings of a cardiologist's examination, noninvasive testing, or cardiac catheterization.

‡ As evidenced by electrolyte abnormalities (potassium, <3.0 meq/L: HCO_3, <20 meq/L), renal insufficiency (blood urea nitrogen, >50 mg/dL; creatinine, >3.0 mg/dL), abnormal blood gases (P_{O_2}, <60 mmHg; P_{CO_2}, >50 mmHg), abnormal liver status (elevated aspartate transaminase or signs at physical examination of chronic liver disease), or any condition that has caused the patient to be chronically bedridden.

Risk Reduction

Several factors included in the multifactorial index of cardiac risk are potentially amenable to preoperative intervention. For example, as already noted, the risks of surgery will be reduced if the operation can be postponed for 3 or preferably 6 months after myocardial infarction, and if congestive heart failure can be controlled by diuresis (but not overtreatment). If a patient is suspected to have important valvular aortic stenosis, a noninvasive cardiac evaluation should be done. If an echocardiogram suggests that significant aortic stenosis may be present in a patient who has angina, heart failure, or syncope, all but emergency surgery should be delayed until the aortic stenosis is fully evaluated, usually by cardiac catheterization. If catheterization shows severe stenosis in a symptomatic

patient, aortic valve replacement usually should precede surgery. If, however, the aortic stenosis is not critical or the patient has no cardiac symptoms despite important valvular stenosis, the patient usually can undergo general surgery. In some patients, however, the stress to be expected from the surgery may be greater than that associated with the patient's regular level of activity, and thus aortic valve replacement may occasionally be recommended in asymptomatic patients with marked aortic stenosis. When patients with important aortic stenosis have general surgery, hemodynamic monitoring (including an intra-arterial catheter and a pulmonary artery catheter implanted before operation and kept in place for about 24 to 48 hours after surgery) is recommended to guide perioperative fluid management.

Coronary Artery Disease

Recently, several authors have proposed the routine use of preoperative exercise tests[26,27] for patients with cardiac disease, the routine use of preoperative coronary angiography for patients with positive exercise test results[26,27] or peripheral vascular disease,[28] and the routine use of pulmonary artery catheterization with hemodynamic measurements before and after fluid adjustments for all patients over age 65 years.[29,30] Although each of the series have reported low rates of surgical complications, none has reported control populations or has compared their observed complication rates with the rates that would be expected based on a multifactorial assessment of cardiac risk. In fact, in the one study, which compared various approaches to estimating cardiac risk for surgery, risk assessment based on conventional noninvasive preoperative factors was as accurate as a risk assessment that also included pulmonary artery hemodynamic measurements with the patient at rest and at exercise.[31]

Issues related to the preoperative evaluation of patients with angina are controversial, and recommendations will often differ depending on the biases of the consultants and the weight of recent local experience. Although our current knowledge does not support any dogma, I believe that the issues regarding exercise tests, coronary arteriography, and pulmonary artery catheterization can be divided into two areas: risk assessment and management. For risk assessment, the history, physical examination, and electrocardiogram should usually be adequate, with the understanding that patients usually do well if stable NYHA class II angina is the only risk factor and that patients with NYHA class IV angina are probably at very high risk. Patients with NYHA class III angina are usually candidates for coronary bypass surgery independent of any issues related to contemplated noncardiac surgery. It is usually prudent to proceed with the evaluation and treatment of the coronary disease before addressing all but emergency surgery. I do not believe that exercise tests are very useful in preoperative decision-making because of serious limitations in their diagnostic use.[32,33] Although the anatomic severity of coronary disease and its prognosis generally correlate with exercise tolerance, there are no controlled data to indicate that exercise testing adds important information for risk assessment or for specific perioperative interventions. Additional cardiac evaluation is sometimes indicated in patients whose noncardiac limitations (such as severe claudication or arthritis) or unreliable histories may mask the true severity of the underlying angina. In patients unable to perform exercise tests, coronary arteriography, with concomitant left atrial pacing to show the clinical importance of any observed anatomic coronary stenoses, is the recommended method for assessing the severity of ischemic heart disease and for deciding whether coronary bypass surgery should precede elective noncardiac surgery. However, I do not recommend coronary arteriography routinely in patients needing vascular surgery[28] because, for patients with truly stable class II angina, the combined risks of infarction or death with catheterization and bypass surgery[34,35] may be greater than the risks of such complications from the noncardiac surgery. After bypass surgery has been done, several series indicate that cardiac risks for noncardiac surgery are low,[21,28,36,37] but the risks of noncardiac surgery in the first 30 days after bypass surgery were high in one series.[38]

Hemodynamic Monitoring

Hemodynamic measurements may be very helpful for the management of patients with known cardiac disease. Although the introduction of sophisticated hemodynamic monitoring has not dramatically reduced the overall percentage of patients who develop cardiac complications after noncardiac surgery in the last 20 years, the ability of older patients to undergo more ambitious operations suggests that the routine intraoperative monitoring done by anesthesiologists may have prevented an increase in complication rates. The apparent reduction in complication rates in patients with recent preoperative infarctions[13,14] is probably related to the use of pulmonary artery catheters and arterial catheters to monitor hemodynamics both during and after surgery. Both our data[10] and the data of others[39,40] indicate that substantial intraoperative hypotension, such as blood pressure decreases of 50% or more or blood pressure decreases of 33% that are maintained for 10 minutes or longer, are associated with marked increases in cardiac risk. Avoidance of excessive preoperative diuresis as well as careful intraoperative management should reduce the risks of hypotension.

TABLE 4. *Relation of Preoperative Hypertension and Treatment to Perioperative Changes in Blood Pressure During Elective Surgery Under General Anesthesia**

	Mean (±SE) Preoperative Systolic Pressure† (*torr*)	Mean (±SE) Intraoperative Systolic Pressure Nadir‡ (*torr*)	Patients with Perioperative Hypertensive Episodes§ *n* (%)	Patients Receiving Intraoperative Fluid Challenge or Adrenergic Agents to Maintain Blood Pressure‖ *n* (%)
Group I: normotensive patients (n = 431)	126 ± 1	94 ± 1	33 (8)	82 (19)
Group II: patients on diuretic therapy without history of hypertension (n = 49)	129 ± 3	95 ± 3	3 (6)	9 (18)
Group III: now normotensive patients receiving therapy (n = 40)	136 ± 2	100 ± 2	21 (27)	16 (20)
Group IV: patients with hypertension despite therapy (n = 40)	154 ± 2	97 ± 3	10 (25)	13 (33)
Group V: patients with untreated hypertension (n = 77)	161 ± 2	98 ± 2	15 (20)	21 (27)

* Adapted from Goldman and Caldera (25).

† All possible pairs are significantly different ($p \leq 0.05$) except group II *vs.* group I.

‡ The only significantly different pair is group I *vs.* group III.

§ Patients in group I had significantly fewer hypertensive episodes than those in group III, IV, or V; patients in group II had fewer episodes than those in group III or IV.

‖ No significant difference among the five groups.

Although there are no data to prove that intra-arterial or pulmonary artery catheters reduce operative risk, hemodynamic monitoring is recommended for patients in class IV on the multifactorial risk index or those in the class III group who have evidence of substantial heart failure, aortic stenosis, or a recent preoperative myocardial infarction. Such monitoring may also be recommended routinely for patients undergoing procedures such as abdominal aortic aneurysm resections, and selectively for very elderly patients or occasional other patients who are felt to be at high risk. Once instituted, monitoring should usually be continued for about 48 hours after surgery, because it is during this period that the fluids given intraoperatively are mobilized into the intravascular space.

Management of Specific Problems

Arrhythmias

Although a preoperative history of arrhythmias is associated with an increased risk of cardiac complications, such complications are commonly manifested as myocardial ischemia or congestive heart failure. This finding is consistent with the observation that the severity of arrhythmias correlates with the degree of coronary artery disease and myocardial dysfunction.[16,17] Because antiarrhythmic prophylaxis will not reduce the risk related to a patient's coronary disease or myocardial dysfunction, prophylactic preoperative or intraoperative lidocaine therapy can normally be reserved for patients with a history of symptomatic ventricular arrhythmias or of "sudden death." The reduction in cardiac output caused by general anesthetic agents may lengthen the half-life of lidocaine, and lidocaine's neurologic toxicity (manifested by somnolence, confusion, and seizures) may be masked by the effects of anesthesia or mistakenly ascribed to other causes in the early postoperative period. In the vast majority of instances, the patient's usual antiarrhythmic medication should be given the morning of surgery, and intraoperative or postoperative lidocaine therapy should be reserved for patients who develop arrhythmias that cause hemodynamic compromise or for the treatment of severe ventricular arrhythmias such as ventricular tachycardia. Needed antiarrhythmic medication should be reinstituted as soon as possible after surgery; quinidine can be given intramuscularly, and procainamide can be given intravenously with careful monitoring of the patient's blood pressure. When used appropriately, measurements of serum levels of antiarrhythmic drugs can aid in the perioperative management of these patients.

General Medical Status

Although there are no controlled data, it is generally believed that improving the patient's general medical condition, including electrolyte abnormalities, marked anemia, hypoxia, or hypercarbia, will decrease the patient's risk of perioperative complications. Elective surgery carries a lower risk than emergency surgery, but the benefits of stabilizing a patient's condition must be balanced against the surgical risks of delaying a procedure.

Hypertension

As mentioned earlier, stable hypertension does not appear to be a major independent risk factor for noncardiac surgery.[8,25] Data suggest that no benefit can be derived from postponing elective surgery to achieve better control

of blood pressure levels in patients with stable hypertension and diastolic blood pressures of 110 mmHg or less[25,41] (Table 4). Perioperative hypertension will occur in about 25% of patients with a history of hypertension regardless of the level of preoperative control, and intraoperative blood pressure changes needing a fluid challenge or adrenergic agents will occur in about 20% to 30% of patients, again independent of the degree of preoperative control.[25] Despite previous concerns about the risks of administering antihypertensive medications to patients about to have surgery,[9,42] substantial subsequent data have confirmed that it is not only safe[43] but probably preferable[44–46] to continue such medications up to and including the morning of surgery.

Propranolol Therapy

Although early studies suggested that propanolol might blunt the appropriate hemodynamic responses to surgery,[47] subsequent data have documented that patients on propranolol do have appropriate responses.[48–50] Because of the risk of propranolol withdrawal rebound in patients who have been on the drug before surgery,[51,52] propranolol should be continued up to the morning of surgery for patients who need propranolol for the control of either marked hypertension or angina.[52] Alternatively, nadolol, a long-acting beta-blocking drug, can be given the morning of surgery in a single dose that is one fourth the usual daily dose of propranolol. Because propranolol's tissue half-life seems to be close to 24 hours, signs of propranolol withdrawal rebound usually will not appear until the evening after surgery or the next morning. Signs of withdrawal rebound include tachycardia and hypertension, which may also be signs of many other conditions such as fluid overload. If a full examination indicates that propranolol withdrawal rebound is the most likely cause of the problem—with the understanding that fluid overload, hypoxia, or inadequate sedation are far commoner causes of tachycardia and hypertension—propranolol should be given and will usually reverse the signs of withdrawal rapidly. If the patient can take oral medications, propranolol should be given orally. If the patient still has a nasogastric tube in place, propranolol can be administered through the nasogastric tube, and sufficient drug will often be absorbed within 30 minutes for the signs of propranolol withdrawal rebound to be neutralized. In certain instances, propranolol can be given intravenously for clear withdrawal signs and symptoms that cannot be controlled by other medications (for example, nitrates or nifedipine in patients with angina; methyldopa or other antihypertensive agents in patients with hypertension). Therapy usually begins with a 1-mg test dose followed by 1 mg every 5 minutes up to a total dose of 10 mg or until signs or symptoms improve, and then 1 mg every 20 to 60 minutes. Alternate regimens include a loading dose of 5 to 10 mg over 60 minutes followed by an infusion of 0.01 to 0.05 mg/min 53, or an infusion of 3 mg/h 54.

Prophylactic Antibiotic Therapy

Guidelines on prophylactic therapy with antibiotics have been published by the American Heart Association.[55] Patients with valvular heart disease or prosthetic heart valves should receive prophylactic antibiotics if their operations are likely to be accompanied by important bacteremias. Antibiotic prophylaxis should be given to patients with valvular heart disease or prosthetic valves if they are having incision and drainage of an infected site, if they have surgery or biopsies of the lower gastrointestinal tract or of the gallbladder, or if they have genitourinary procedures in the presence of bacteriuria. For patients with valvular heart disease, prophylactic antibiotics are not recommended for vaginal delivery, or for "upper gastrointestinal endoscopy (without biopsy), percutaneous liver biopsy, proctoscopy, sigmoidoscopy, barium enema, pelvic examination, dilatation and curettage of the uterus, and uncomplicated insertion or removal of intrauterine devices".[55] Prophylaxis is recommended, however, when such procedures are done on patients with prosthetic valves.

Because bacteremias from genitourinary or gastrointestinal sites often include enterococci, prophylactic antibiotic regimens should be sufficient to cover such organisms. Gram-negative organisms from gastrointestinal and genitourinary sites may cause bacteremia, but they rarely cause endocarditis except in patients with prosthetic valves. The current recommendations[55] for adults suggest administration of aqueous crystalline penicillin G or ampicillin (intramuscularly or intravenously) plus gentamicin (intramuscularly or intravenously) or streptomycin given as an original dose 30 to 60 minutes before the procedure and then repeated for two additional doses (given at 8 to 12 hours and 16 to 24 hours after the procedure). If the patient is allergic to penicillin, vancomycin (1 g intravenously given over 30 to 60 minutes) plus gentamicin or streptomycin can be given 30 to 60 minutes before the procedure and then repeated once at about 12 hours after the procedure.

Prophylactic Digitalis Therapy

Although prophylactic treatment with digitalis will reverse much of the myocardial depression induced by general anesthetic agents in experimental animals,[56,57] prophylactic digitalis therapy for patients without definite heart failure has never been proved to be beneficial. Thus, preoperative digitalis therapy can be reserved for patients

who have definite signs of congestive heart failure that would normally need long-term digitalis treatment. However, there is evidence to suggest that digitalis may help control the ventricular response rate of patients who develop postoperative supraventricular tachycardias.[19,58] Prophylactic preoperative digitalis therefore is recommended for patients who have very high risk for supraventricular tachycardias: elderly patients undergoing pulmonary surgery, patients with subcritical valvular heart disease who might tolerate such an arrhythmia poorly, or patients currently not on medication who have a history of paroxysmal tachycardias.[19,58] Patients with premature atrial contractions may also have an increased risk for postoperative supraventricular tachycardias, but not such high risk as to make mandatory prophylactic digitalis therapy.[19]

Pacemakers

Patients who have bifascicular block, with or without prolonged PR intervals or atrial fibrillation, seem to have an increased risk of developing complete heart block during long-term follow-up.[59–61] However, the likelihood that complete heart block will develop acutely with surgery is well less than 1%.[10,62,63] The risk of serious bradycardias in patients with sick sinus syndrome is less clear, but it is suggested that prophylactic pacemakers be reserved for those patients who will need chronic pacemakers. If such a patient is about to undergo surgery in which a bacteremia is likely to occur, a temporary pacemaker should be implanted before the operation, and a permanent pacemaker should be implanted after the risk of bacteremia is over.

Asymmetric Septal Hypertrophy and Mitral Valve Prolapse

There are few data on the operative risks in patients with asymmetric septal hypertrophy, with or without obstruction. The peripheral vasodilatation induced by spinal anesthesia can be treated by fluid administration, and beta-adrenergic agents should be avoided. Patients with mitral valve prolapse are probably not at increased risk for surgery unless they have significant mitral regurgitation and congestive heart failure. However, patients whose mitral valve prolapse is manifested by an audible murmur have an increased risk of bacterial endocarditis[64] and should receive the same antibiotic prophylaxis given to other patients with native valvular lesions.

Prosthetic Valves

Patients with prosthetic heart valves probably have no higher risk of congestive heart failure, ischemia, or arrhythmias than patients with native valvular abnormalities and similar degrees of congestive heart failure. Such patients, however, do have a substantial risk of problems related either to the continuation or discontinuation of anticoagulants.[65] In planning perioperative anticoagulation strategies, physicians should consider that bleeding usually can be controlled whereas a single cerebral embolus can be devastating. One alternative is to discontinue oral warfarin therapy about 2 days before surgery, and to resume the treatment 1 to 3 days after surgery; in one series,[66] the hemorrhagic complication rate of such a regimen was 13%. An alternative is to discontinue oral anticoagulant therapy 3 to 5 days before surgery, with or without reversal by vitamin K; begin and continue full-dose heparin treatment until 6 hours before the surgery; and resume heparin administration 12 to 24 hours after the operation. Warfarin therapy can be started when the patient is able to take oral medication. Using this approach, the hemorrhagic complication rate is probably similar to the simpler regimen described.[67] With either regimen, the risks for development of thromboembolic complications is very small, although anecdotal data from our hospital suggest that the second regimen may be preferable for patients with the highly thrombogenic, caged disk valves. As noted above, patients with prosthetic valves also need antibiotic prophylaxis for any procedures in which bacteremias might be expected to occur.

Anesthesia and Intraoperative Care

Although medical consultants may often be tempted to debate on the appropriate anesthetic agent or route of anesthesia for a patient with cardiac disease, anesthesiologists have far more expertise in this area. Furthermore, virtually all data suggest that the type of general anesthetic agent is rarely important.[2,4,6,10] Halothane, which causes peripheral vasodilatation as well as myocardial depression, is more often associated with hypotension than are other agents,[25] but even these potential side effects are well known by anesthesiologists and can be aborted by careful intraoperative care.

The anesthesiologist is a critical member of the management team for cardiac patients undergoing noncardiac surgery, and the medical consultant should not underestimate the expertise that the anesthesiologist brings to the patient's care. All too often, relatively inexperienced medical physicians may attempt to dictate intraoperative strategies or may offer trite and unappreciated warnings such as to "avoid hypotension." As emphasized by Kaplan and colleagues,[13,21,68] anesthesiologists who are experienced in the care of patients undergoing coronary artery bypass surgery or valve replacement procedures also can have an especially valuable role when the patient with cardiac disease has major noncardiac surgery.

Abundant data indicate no difference in the risk of

intraoperative hypotension with spinal anesthesia compared with general anesthesia, and therefore there is no clear benefit to spinal anesthesia for patients with ischemic heart disease.[4,10] Furthermore, many patients will not be adequately sedated with spinal anesthesia, or may be so fearful that spinal anesthesia will actually cause more myocardial stress than well-balanced general anesthesia. Data do suggest, however, that congestive heart failure is less likely to be worsened by spinal anesthesia,[10] presumably because spinal anesthetics are not direct myocardial depressants, whereas general anesthetics are. In our series, after general anesthesia and surgery, heart failure developed de novo in 4% of adults over age 40 years and worsened in 22% of patients with a history of heart failure; by comparison, spinal anesthesia was not associated with new or worsening heart failure.[10] Although these uncontrolled data are not ideal, they do suggest that spinal anesthesia can be recommended from a cardiac standpoint only in patients with preoperative evidence of substantial congestive heart failure. Of course, spinal anesthesia may sometimes be preferable to general anesthesia for pulmonary reasons, but again the anesthesiologist commonly will be more experienced than the internist in this regard.

Postoperative Complications

Postoperative hypertension usually occurs within 30 to 60 minutes after the end of anesthesia, and it is commonly precipitated by pain, excitement, discomfort from the endotracheal tube, hypoxia, hypercarbia, hypothermia, or fluid overload.[69] Early postoperative hypertension may occur in about 50% of patients who have abdominal aortic aneurysm surgery[25] and in about 30% of patients who have peripheral vascular procedures, including carotid endarterectomy.[25,70] Hypertension at this time may be best controlled with oxygen, sedation, and adequate analgesia. If hypertension is very marked, intravenous administration of nitroprusside is the best therapy because its rapid onset of action and short half-life permit the dose to be modified quickly if the clinical situation is changing. For lesser degrees of hypertension unresponsive to conservative measures, low-dose hydralazine therapy is usually effective. However, high-dose hydralazine therapy, such as 10 mg given intravenously, may precipitate supraventricular tachycardias or myocardial ischemia in patients with cardiac disease. In hypertensive patients after surgery, hydralazine should be used in small doses (such as 2 mg intravenously as a test dose and then 5 mg repeated every 15 to 20 minutes in an attempt to titrate blood pressure without causing sudden reflex sympathetic side effects). Methyldopa is an effective antihypertensive agent, but even when given intravenously it usually does not have its onset of action for about 4 hours. Methyldopa should be given to patients with substantial postoperative hypertension, with an understanding that it may be very beneficial several hours later when sedation and analgesia begin to wear off. Unless the blood pressure remains very high for 3 or more hours, perioperative hypertension rarely causes other cardiac problems.[25,69]

The second time for postoperative hypertension is between 24 and 48 hours after surgery when the patient begins to mobilize intraoperative fluid. Hypertension at this time is best treated with mild diuretics, or by observation. It is also important that chronic antihypertensive medications be restarted in the hospital for patients with a history of hypertension; if the patient had marked hypertension, treatment should be started as soon as the patient resumes oral medication.

Postoperative ventricular premature beats are often precipitated by hypoxia, pain, or fluid overload. In the recovery room, such arrhythmias are usually best treated with oxygen, sedation, analgesia, and correction of any fluid or electrolyte abnormalities that might be discovered. Specific antiarrhythmic therapy is less commonly required, unless the patient has hemodynamic compromise or has frankly life-threatening arrhythmias.

Postoperative supraventricular tachyarrhythmias are primarily caused by cardiovascular problems only about 30% of the time.[19] Other common precipitants include infection, new medications, electrolyte abnormalities, or hypoxia. The predisposing cause of the arrhythmia also explains the best approach to these patients. Attention should usually be directed toward correction of the underlying medical problem, with an understanding that changes in cardiac medications will be needed in only about half of the patients. Electrical cardioversion is rarely needed, and patients rarely die from complications of the arrhythmia itself; however, up to half of patients with new postoperative supraventricular tachycardias die because of their underlying medical problems.[19] In patients who have no important underlying heart disease, antiarrhythmic medications that were started because of a new postoperative supraventricular tachycardia can usually be discontinued at or before hospital discharge.

Postoperative heart failure tends to have the same biphasic peak as postoperative hypertension. The first peak occurs in the recovery room and is related to the discontinuation of positive pressure respiratory assistance. The second peak occurs 24 to 48 hours later and is related to the mobilization of intraoperative fluid. Although heart failure may occasionally be precipitated by myocardial ischemia or infarction, in up to half of the patients, postoperative heart failure can be directly attributed to excess fluid administration.[71] Diuretics are the mainstay of treatment, and patients should not be committed to long-term therapy based solely on a single perioperative episode of heart failure.

The tendency for postoperative medical and surgical problems to precipitate cardiac complications can also be appreciated by observing the time of onset of most perioperative myocardial infarctions;[10,63] about 60% of infarcts occur in the first 3 days after surgery, and most of the rest occur between the fourth and sixth postoperative days.[2,10] In many series, the peak risk of postoperative infarctions is 3 to 5 days after surgery. Infarctions are most likely to occur after surgery when patients are mobilizing intraoperative fluid, being withdrawn from analgesics, or beginning to walk about. Thus, postoperative recuperation, especially if it is not progressing smoothly, is more likely to precipitate myocardial ischemia than is well-balanced general anesthesia. Based on this time course, the medical consultant must be sure to follow hospitalized patients with ischemic heart disease for at least 6 days after the operation.

Because up to half of postoperative myocardial infarctions present without pain,[10] the physician must be alert for arrhythmias, hypertension, hypotension, or altered mental status that may herald painless postoperative infarctions. Although postoperative myocardial infarctions will rarely be discovered on a routine postoperative electrocardiogram in a patient who has no signs or symptoms,[10] it is probably worthwhile to obtain an electrocardiogram in the early postoperative period and again on the third to fifth postoperative day in patients who are in risk classes III or IV by the multifactorial index or who have a history of angina or infarction. More frequent postoperative electrocardiograms would be suggested only for patients who are at especially high risk or who have signs or symptoms that suggest ischemia. It should be noted that postoperative myocardial infarctions have about a 50% mortality rate even with modern medical care.[10,63]

The diagnosis of a postoperative myocardial infarction may sometimes present a major challenge to the clinician. In patients with suspected myocardial infarctions, it may be difficult to distinguish ischemic ST-T wave changes from the electrocardiographic changes that are occasionally seen with major abdominal diseases. Measurement of serum enzymes often will be helpful in this regard, but the aspartate transaminase (AST) and lactic acid dehydrogenase (LDH) levels will often be elevated in patients who have had biliary surgery, and AST and creatine kinase levels are commonly elevated after abdominal or orthopedic procedures.[72-74] Creatine kinase isoenzymes will be substantially more reliable,[75] and the MB isoenzyme fraction will rarely be greater than 5% of the total creatine kinase value in patients who have muscle trauma only. In the absence of hemolytic anemia or renal infarction, determination of LDH isoenzymes may also be helpful in the diagnosis.[76] Technetium pyrophosphate scans, which are usually positive in patients with transmural myocardial infarctions, are less helpful in patients in whom subendocardial infarctions are uncertain despite the availability of data from routine enzyme measurements and electrocardiograms.[77,78]

It is important to emphasize that the internist's consultative role includes the responsibility to take an independent preoperative history and do a physical examination as well as to interpret existing data or answer preconceived questions. The consultation should address global and specific risks, and it should identify ways to reduce risks and manage particular problems. Finally, the internist must remember that the surgery and the immediate postoperative period are only the beginning of the potential for problems. The risks of postoperative hypertension, arrhythmias, and congestive heart failure persist for at least 2 days, and the risks of myocardial infarction persist for 5 to 6 days after surgery.

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